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SHORELINE CHANGES IN THE GIPPSLAND LAKES 1957-1983

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Abstract: In 1982-83 the shoreline of the Gippsland Lakes was re-surveyed at locations originally mapped in 1957-59 to determine the extent of advance or retreat over the intervening period. It was found that shoreline erosion had become more extensive, with many sectors of sandy, swampy or deltaic shoreline having retreated at least 2 m: on the Mitchell delta recession has been up to 5 m, and on the Tambo delta up to 30 m in the past 25 years. Progradation has been confined to a few sectors where swamp encroachment continues, and where sand has accumulated on spits and in embayments. Several sectors, including the shoreline of the Mitchell delta, have been stabilised artificially. It is predicted that the Gippsland Lakes shoreline will become increasingly sandy as sand loads moving down the Latrobe, Avon and Tambo Rivers begin to flow into the Lakes. Dumping of dredged sand on the lake shores is also increasing the extent of sandy beaches, but could have adverse ecological and environmental effects.

It is now well established that the coastal lagoons known as the Gippsland Lakes (Fig. 1) in eastern Victoria developed as the result of the successive deposition of sandy barrier formations across a broad marine embayment on the East Gippsland coast in Late Quaternary times (Bird 1965, 1978, Jenkin 1968). Enclosure of the existing lagoons (Lakes Wellington, Victoria, King and Reeve) occurred in Holocene times when, as a sequel to the major marine transgression that produced the broad outlines of the present coast, an outer sandy barrier formed, with the Ninety Mile Beach on its seaward side. When European explorers reached this area in the eighteen-forties the Gippsland Lakes had only a variable and intermittent outlet to the sea east of the township of Lakes Entrance, but in 1889 a permanent artificial entrance was opened (Bird & Lennon 1973), and the lakes, until then relatively fresh water systems, became estuarine lagoons.

Previous studies have shown that the Gippsland Lakes, enclosed behind and between sandy barrier formations, have shorelines which are being shaped by several processes: 1, wave action, which has cut out embayments and built up beaches and spits. In some areas the cutting of bays and growth of intervening spits has proceeded in such a way as to convert the previously long, narrow lagoons into chains of smaller, more rounded lagoons, a process termed segmentation (Zenkovich 1967); 2, current action, which has contributed to this segmenting process, and also initiated meandering of narrow straits, especially in the more tidal eastern region, where Hopetoun Channel winds towards Lakes Entrance; 3, swamp encroachment, initiated by the growth of reedswamp (mainly *Phragmites*, accompanied by *Typha*, *Cladium*, and other plants) in shallow nearshore water, prograding depositional terraces that are invaded by swamp scrub (mainly *Melaleuca ericifolia*); 4, fluvial sedimentation, notably at the mouths of the Mitchell, Tambo, Avon and Latrobe Rivers; and 5, deposition of sandy material washed or blown over narrow sections of the outer barrier, particularly in Bunga Arm and Cunninghame Arm.

As a sequel to increased salinity in the Gippsland Lakes since the opening of the artificial entrance, much of the reedswamp fringe has died back, and erosion has ensued on low-lying swampy and deltaic shorelines around Lake King and Lake Victoria, and to a lesser extent in the relatively fresh Lake Wellington. This sequence was described and discussed by Bird (1978) on the basis of detailed field studies in 1957-59 and subsequent investigations.

In the summer of 1982-83 the shorelines of the Gippsland Lakes were revisited to assess the nature and extent of changes since 1957-59, especially on sectors that were surveyed and photographed during the earlier field studies. Attempts to measure shoreline changes from air photographs of various dates and scales were not successful because it is rarely possible to determine changes within ± 2 m by this method. Measurements were therefore made with reference to identifiable fixed points on the 1957-59 surveys which could still be located on the ground. It is difficult to make precise measurements of changes on cliffed shorelines of intricate outline (minor bays, promontories, and stacks), or on sandy beaches where the waterline can vary by up to 3 m horizontally in relation to oscillations of the lake level. Given these constraints it was decided to classify the shoreline into three categories: stable, advance or retreat of less than 2 m, and advance or retreat of more than 2 m over the past 25 years (Fig. 1). The present paper summarises the evidence for these changes, and discusses further changes likely to take place in the next few decades.

SHORELINE CHANGES

Lake Wellington

Erosion has become more extensive on the shoreline of Lake Wellington since 1957, largely because of further reductions in the extent and vigour of reedswamp growth, and the onset of wave scour on swampy terrain no longer protected by a reedswamp fringe. This is particularly evident on the southern shore of the lake, which now has only a few scattered stands of reedswamp, and on the western side of the Avon delta,

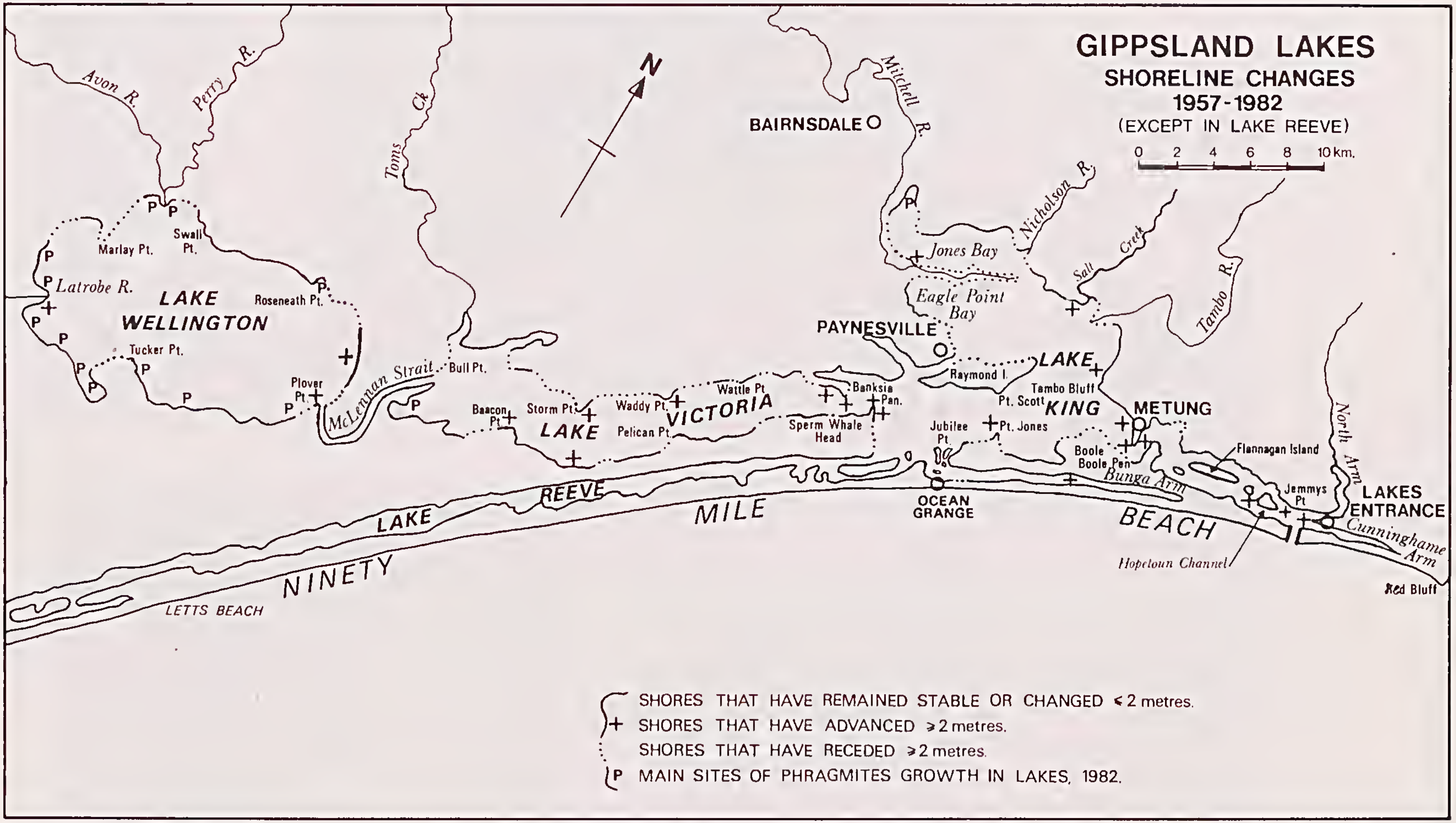

Fig. 1 – Shoreline changes in the Gippsland Lakes.

Fig. 2—The beach on the eastern shore of Lake Wellington has prograded by about 3 m in the period between May 1958 and May 1983, when this picture was taken. Repeated transects along the fence line have shown an advance of the shoreline and the development of a wide backshore zone of marram grass here during this period. Photo: Eric C. F. Bird.

which has lost much of the reed fringe that existed in 1957. In both cases swamp scrub land, no longer protected by a reedswamp fringe, is being eroded by wave action. Where the reedswamp fringe persists, as on the eastern side of the Avon delta and around the mouth of the Latrobe River, accretion of silt and clay within this fringing vegetation has continued to advance the shoreline: at the mouth of the Latrobe, sedimentation in reedswamp has led to an advance of about 20 m since 1957.

The reduction in extent of reedswamp on the shores of Lake Wellington is probably related to variations in water salinity in this lake during the past 25 years. Much of the salt in Lake Wellington is derived from the inflow of sea water through the artificial entrance, diluted as it spreads through Lakes King and Victoria and into Lake Wellington by way of McLennan Strait. There are also minor and local accessions of brackish water from creeks and drains that discharge runoff from bordering salt marshes and saline flats, notably the drain from Lake Kakydra into Lake Wellington west of Marlay Point. Nevertheless, Lake Wellington remains the least brackish of the Gippsland Lakes, being remote from the artificial entrance. In 1958 surface water salinity in the middle of this lake ranged from a maximum of 12.0‰ in June to a minimum of 0.1‰ in December, typical of a seasonal fluctuation related to diminished rainfall and runoff and increased evaporation in summer and autumn (maximum salinity May-June), followed by increased freshwater inputs in winter and spring (minimum salinity November-December). Occasionally, as in February 1971, heavy rainfall in the catchments of the Latrobe and Avon Rivers results in the discharge of floodwaters into Lake Wellington, which is thus temporarily freshened. During droughts, on the other hand, surface water salinity increases in Lake Wellington: during the 1967-68 and 1982-83 droughts it rose to more than 20‰ in the middle of the lake.

The possibility of an overall increase in the salinity of Lake Wellington in recent decades was suggested by Bird (1978) on the grounds that mean monthly surface salinity in 1957-60 was generally below the 20-year (1957-76) average whereas equivalent means in 1972-76 were above it. However, a more detailed statistical analysis by Mobley *et al.* (1983) failed to substantiate such an increase, and it now seems likely that impeded growth and die-back of reedswamp on the shores of Lake Wellington is due to the recurrence of high salinity in dry years (Clucas 1980). During the dry summer of 1982-83, when die-back of reedswamp was observed at several locations on the shores of Lake Wellington, salinity measurements in the southeastern part of the lake, off Plover Point, rose to a maximum of 22.5‰ in April 1983.

Surveys made in 1982-83, on transects originally mapped in 1957-59, indicate that much of the swampy shoreline around Lake Wellington has receded by up to 2 m, while near Marlay Point, and west of Plover Point, swampy shorelines have retreated by up to 3.5 m. In recent years, walls have been built to halt the shoreline recession at Marlay Point.

Sectors of the Lake Wellington shoreline bordered by sandy beaches have changed only slightly during the past 25 years. Sand eroded from the cliffs at Roseneath Point has been carried southwards to prograde the beach on the eastern shoreline by up to 3 m (Fig. 2) and sand accretion on Plover Point has built up a cuspate foreland. On parts of the southern shoreline, sand has been washed up on to bordering swamp land to form chenier-like ridges behind low receding cliffs cut in

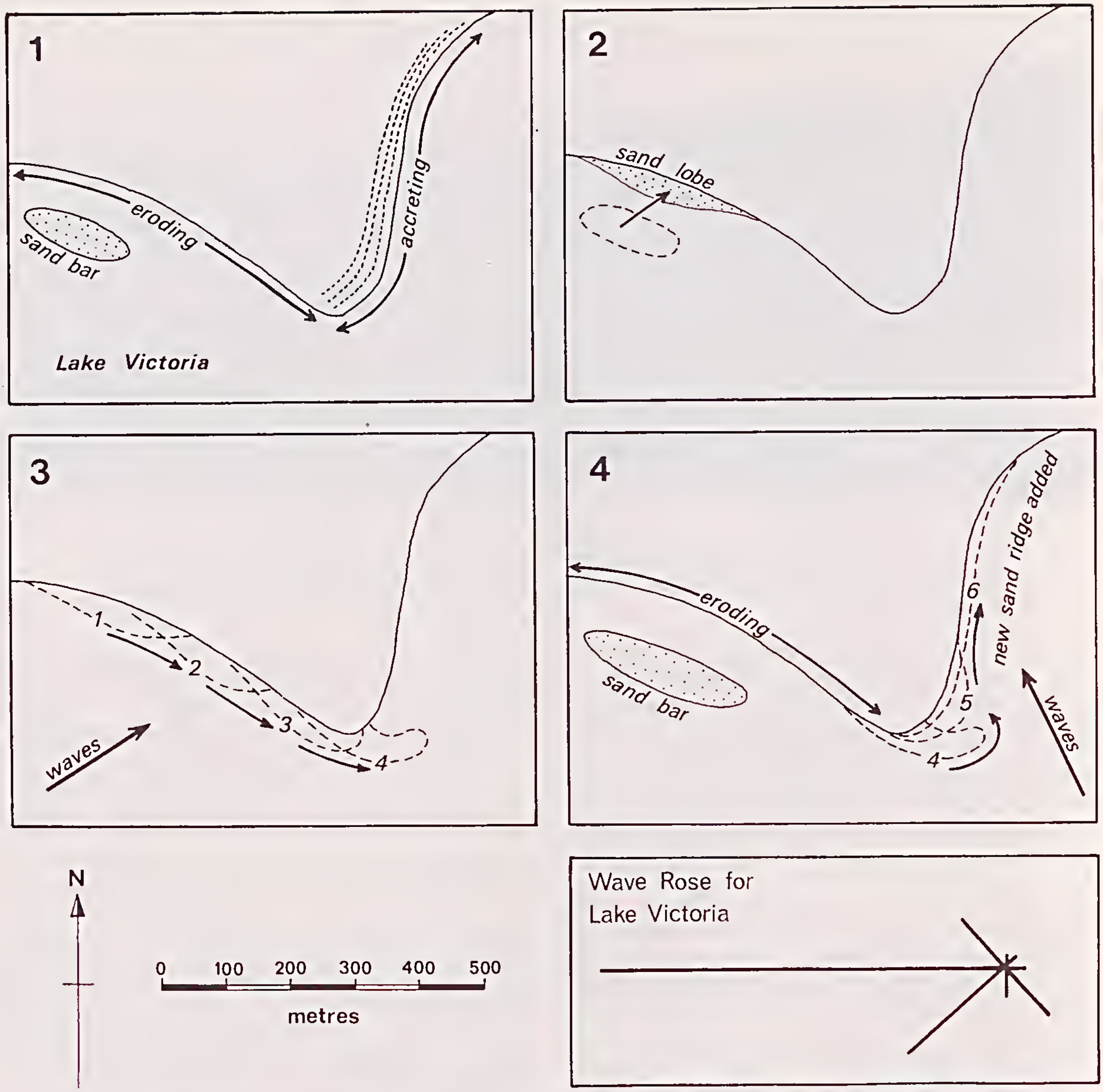

Fig. 3—Sequence on changes on cuspate forelands on the north shore of Lake Victoria, notably at Waddy Point (after Woodburn 1978).

swamp deposits. On Tucker Point the fine gray sandy beach has evidently been derived from sandy sediment of similar colour washed into Lake Wellington by the Latrobe River during floods. Studies of sandy sediment moving down the Latrobe indicate that this supply will increase in the future. Successive floods have already moved large quantities of sand down the river channel to below Rosedale, and the date of arrival of this material at the river mouth will depend on the frequency and severity of future flooding (Bird *et al.* 1979). The same is true of the Avon, which in the 1971 floods delivered a large shoal of sand to the lake floor south of Strathfieldsaye. This was subsequently re-worked by wave action and carried on to lake-shore beach sectors at Marlay Point and Swell Point (Bird 1972). Such sand, travelling as bed-load, is not retained in the reed fringe at the mouth of the river; it is the suspended material, silt and clay, which becomes trapped in bordering reedswamp and thus added to the delta shoreline. In due course the augmented sand loads from the Latrobe and the Avon will nourish more extensive sandy beaches on sectors of the Lake Wellington shoreline that are at present swampy. It is also possible that the arrival of large quantities of sand at the mouths of these rivers will result in the growth of new, sandy deltas, the evolution of which will not depend on the presence of a reedswamp fringe.

LAKE VICTORIA

Much of the swampy shoreline of Lake Victoria was already eroding in 1957. Erosion has continued, especially in the western part of the lake, north of the delta at the eastern end of McLennan Strait, where the reedswamp fringe present in 1957 has disappeared, and shoreline recession of up to 3 m has ensued. Cliffed sectors of the sandy shoreline of the inner barrier, which forms the southern boundary of this lake, have also retreated by up to 3 m, although the recession of several cliffs cut into dune sand has been reduced by the introduction of shore protection works, mainly timber fencing and brushwood groynes.

The most obvious changes have occurred on spits and cuspate forelands, mainly along the northern shore of this lake, which shows a succession of these depositional features between eroded bays. Woodburn (1978) examined the evolution and dynamics of Storm Point, Waddy Point, Wattle Point, Point Turner on Banksia Peninsula and Point Scott on Raymond Island. Each are cuspate forelands of similar configuration, their western flanks showing evidence of erosion, yielding beach material which travels eastward, around the point, for deposition on prograding eastern shores. On Waddy Point Woodburn made repeated surveys which demonstrated the shoreward movement of a sand shoal from the lake floor on to the western shore. Progradation was only temporary, however, for the beach sands soon drifted round the point, to be added as a new beach ridge on the eastern shore (Fig. 3).

Such growth and migration of spits, accompanied by erosion of intervening bays, is the outcome of relatively strong wave action diagonally across the lake, especially from a westerly direction, and occasionally from the southeast. If it continues there will eventually be segmentation of Lake Victoria (Fig. 4), which has already been separated from Lake Wellington by a similar process of spit growth (Bird 1978).

Sand arriving from the west has enlarged the cuspate foreland at Elbow Point, on the southern shore of Banksia Peninsula, since 1957, and on the northeast corner of Sperm Whale Head sand eroded from the dune cliffs to the west and south has arrived to form a convergent spit, which has grown out from Point Wilson during this period.

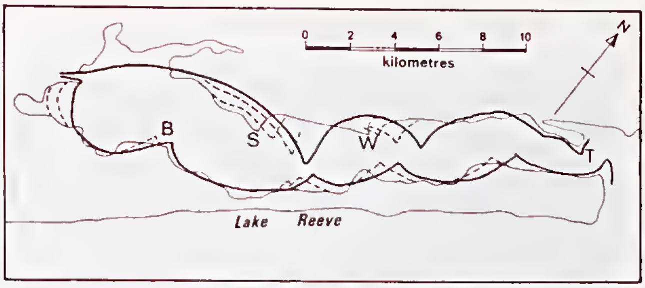

Fig. 4—Future segmentation of Lake Victoria may result from the growth and migration of bordering cuspate spits and forelands. S—Storm Point, B—Beacon Point, W—Waddy Point, T—Turner Point.

LAKE KING

As in Lake Victoria, swampy shorelines already eroding in 1957 have continued to retreat, by up to 3.5 m, in the ensuing period. Erosion has been most rapid on the silty deltas of the Mitchell and Tambo Rivers. Bird and Rosengren (1971) traced stages in the reduction of the Mitchell delta from 266 hectares in 1848 to 178 hectares in 1940 and 145 hectares in 1970, and predicted its dissection into chains of silty islets by the year 2000. Between 1957-59 and 1982-83 erosion continued on this delta shoreline, with losses of up to 5 m locally, but in recent years the Public Works Department has stabilised much of the Mitchell delta by dumping granite and sandstone boulders along its more exposed shorelines (Figs 5, 6), and further dissection is now unlikely. However, it is possible that this armouring will cause deepening of the nearshore waters by reflected wave scour.

The breach that formed through the northern part of the delta, just downstream from Eagle Point Bluff, in 1919 is a deltaic crevasse that has persisted as 'The Cut'.

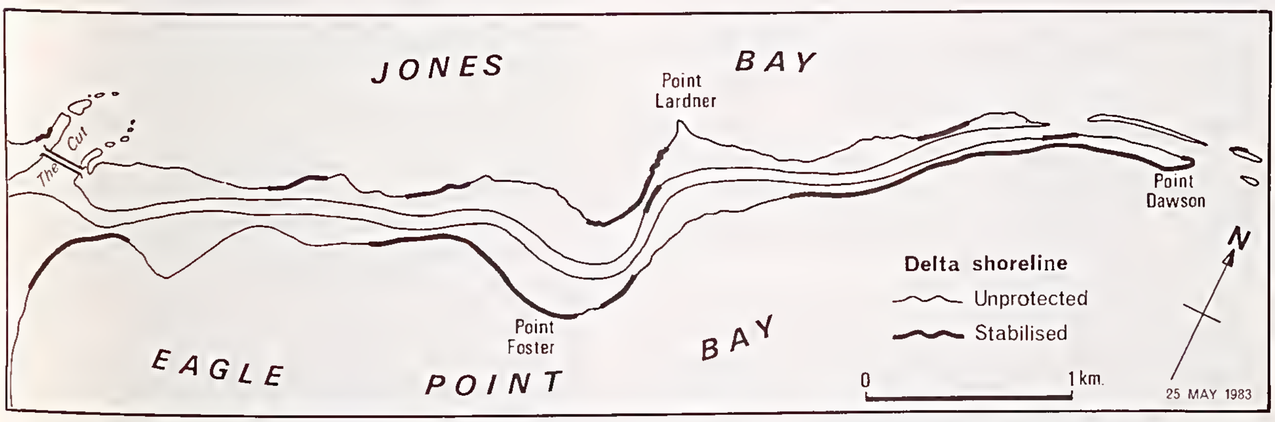

Fig. 5—Sectors of the shoreline of the Mitchell delta stabilised by the addition of boulder walls (as on 25 May 1983).

Fig. 6 — Rapid shoreline erosion on the Mitchell delta has been halted by the dumping of granite and sandstone boulders to form a protective shoreline wall. Photo: Eric C. F. Bird.

A minor deltaic feature has since grown out into Jones Bay as the result of deposition of sand, silt and clay washed down from the Mitchell River (Fig. 7). A lobate deposit has developed, the emerged parts of which carry rushes, sedges, and occasional *Phragmites* reeds, but fluvial sediment has not been trapped in the form of elongated jetties of the kind that developed the earlier Mitchell delta. This is because reedswamp no longer grows out in the shallow water of Jones Bay. In the absence of reedswamp, fluvial sediment has been more widely dispersed into Jones Bay, some of the sand having drifted along the northern shore of the Mitchell delta to accumulate as a beach on the western side of Point Lardner.

Erosion has continued on the northern shore of Jones Bay, especially near the mouth of the Nicholson River, and sand, drifting eastwards along the shore, has enlarged the spit which deflects the mouth of Salt Creek. Sand has also accumulated in the bays on either side of the Tambo delta, but this protruding silty delta has been further reduced by erosion along its lake shores and recession of river banks in the lower reaches (McRae-Williams *et al.* 1981, fig. 54). Since this delta was first surveyed in 1849 its area has been reduced by 11.2 hectares, of which 3.4 hectares were eroded between 1940 and 1977. Recession of the western shoreline since 1957-59 has been up to 30 metres, representing the greatest erosional change found in the Gippsland Lakes over this period, despite successive attempts to stabilise the shoreline with walls and groynes. However, as with the Avon and the Latrobe, sand is moving down the Tambo River, and in due course this is likely to become an area of shore sand accretion.

Swampy shorelines south of Eagle Point Bay and along the northern side of Raymond Island have receded by up to 3 m in the past 25 years, but erosion alongside McMillan Strait at Paynesville has been controlled by the building of shoreline walls.

Locally there has been sand accretion on beach-fringed sectors around Lake King since 1957-59. Beaches have been widened at and north of Tambo Bluff and in the bay north of Jubilee Point, while the spit at Point Jones has been enlarged by the accumulation of sand washed in from the lake floor. East of Point Jones, swampy shorelines have been cut back, particularly on the more exposed sectors, which have retreated by more than 2 m since 1957-59. At Metung the west-facing beach has been augmented artificially by dumping sand dredged from the Tambo River to offset earlier erosional losses (R. Bull, pers. comm.). Some of this sand has drifted south to be added to the end of Shaving Point, and there has also been sand accretion on the shore of the Boole Boole Peninsula east of Metung.

South of Lake King the Bunga Arm is a long, narrow lagoon behind the dune-covered outer barrier and the Ninety Mile Beach. In general these dunes are held in place by a dense cover of scrub and woodland vegetation, but a sector about 10 km east of Ocean Grange has been modified by the growth of a blowout which has delivered wind-blown sand to the lagoon shoreline, resulting in the formation of sandy beaches, spits and cuspate forelands. A wide triangular fan of sandy sediment now extends half way across the lagoon at this point. In 1957-59 sand was still being blown into the Bunga Arm here, but subsequently the dunes have become covered by marram grass and stabilised. The sand supply to Bunga Arm has thus almost ceased, and the beaches, spits and cuspate forelands are no longer growing. However, they are still being re-shaped by wave action, and eventually they could grow in such a way as to produce segmentation of Bunga Arm.

In the eastern part of Lake King, between Metung and Lakes Entrance, shoreline changes have been generally slight. Erosion of swamp land has continued at the mouth of Chinaman Creek, near Metung, and along the lake shore south of Flannagan Island, but there has been some sand accretion on the spits bordering Flannagan Island. Sand dredged from the lake floor to maintain navigable channels has been dumped to reclaim marshland and shallow embayments on Rigby Island

Fig. 7—The spatulate pattern of accretion outside The Cut, a gap through the northern arm of the Mitchell River delta, as the result of the deposition of fluvial outwash in Jones Bay. Most of the deposition is underwater, but minor deltaic formations have developed at A and B, marking local progradation of the shoreline.

Photo: Neville Rosengren.

and to create new land on and around Bullock Island, near Lakes Entrance. The use of such sand to fill bays and marshes and form lake-shore beaches should be preceded by an environmental impact assessment, for it could have ecological effects, particularly where the dumped material obliterates salt marsh vegetation or nearshore *Zostera* beds, thereby modifying habitats for fish and bird life.

Cunninghame Arm, at and east of Lakes Entrance, has been changed since 1957-59 by the extension of sea walls along its northern shore, and by the eastward migration of sand spits and cuspate forelands along its southern shore (Fig. 8). As in Bunga Arm, these sandy formations were being nourished in 1957-59 by wind-blown sand spilling across the outer barrier at several points. Previously, the accumulation of such sandy material at the eastern end of Cunninghame Arm had reduced and segmented the formerly navigable waterway (Reeve River) that led to the variable, migratory natural outlet from the Gippsland Lakes before the present artificial entrance opened in 1889 (Bird & Lennon 1973, Miles 1977). In the nineteen-sixties, planting of marram grass by the Soil Conservation Authority stabilised the dunes on the outer barrier and reduced the sand spillover into Cunninghame Arm. As a result the beaches and spits on the southern shore of Cunninghame Arm were no longer nourished by this process.

The scalloped southern shore of Cunninghame Arm, with its eastward-drifting spits (Fig. 9), has shown little net change since 1957, but the distribution of sand has been modified. In recent years a new source of sand has been produced by the dumping of dredged material on the southern shore opposite the township of Lakes Entrance, and this is being carried eastwards by longshore drifting. It is likely that the sandy material thus provided will eventually accumulate east of the footbridge, shallowing and shrinking Cunninghame Arm. Such changes are likely to be resented by people who now use Cunninghame Arm for fishing and water-borne recreation, and by those who would wish to retain this lagoon as a scenic feature in the environment of Lakes Entrance.

Lake Reeve

Lake Reeve is an elongated lagoon between the inner and outer barriers south-west from Sperm Whale Head. Its eastern part is a branch of the Gippsland Lakes which shallows rapidly south-westwards, much of it being generally a dry muddy sandflat, submerged only after heavy rains, or when easterly winds or river flooding raise the water level in the southern part of Lake King, driving water south-westwards. Salt marshes dominated by *Salicornia* spp. are extensive around its shores, many sectors of which are bordered by low, parallel beach ridges, typically up to 20 cm high and spaced at intervals of up to 60 m.

Shoreline surveys in 1957-59 were less detailed in Lake Reeve, but comparison of air and ground photographs taken during that period with the present configuration shows that on some sectors up to three new beach ridges have been formed, representing an advance of the shoreline of up to 10 m in this period. The pattern is too intricate to be included in Fig. 1. Observa-

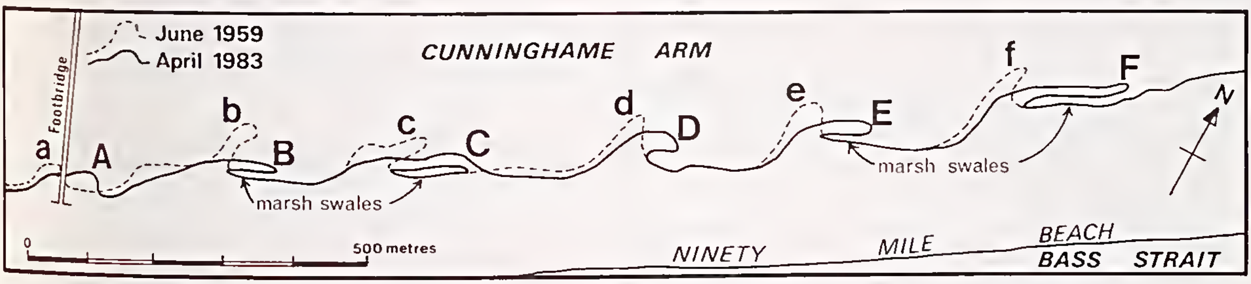

Fig. 8—Comparison of surveys of the sandy southern shoreline of Cunninghame Arm in 1959 and 1983 show that cuspate spits have moved eastwards (a→A, b→B, etc.) and developed longer, flatter alignments, in some cases enclosing small salt marsh swales.

Fig. 9—The southern shoreline of Cunninghame Arm, Lakes Entrance, looking eastward to Red Bluff. Sand spits, formerly nourished by dunes spilling over the enclosing barrier (especially at X), and now augmented by dredged sand dumped on the shore (Y), are migrating eastwards. A to F are the features shown in Fig. 8.

Photo: Eric C. F. Bird.

tions in recent years have shown that the beach ridges form during phases when Lake Reeve is occupied by water for periods of several months (as in 1971). Wave action, chiefly from westerly directions, then washes sand, silt, and the abundant small shells (mainly *Coxiella striata*) up on the margins of the lake, lodging them against the edge of the salt marsh vegetation. When the lake dries out, wave action ceases and the ridges become stable features. Vegetation then colonises them, and *Salicornia* spreads forward from the newly-formed ridge, forming a new salt marsh fringe. When Lake Reeve is next awash, another beach ridge may be added at the salt marsh edge, some distance in front of its predecessor (Fig. 10).

As a result of this recurrent beach ridge formation, Lake Reeve has been reduced in area. For this reason the ridges have been termed contraction ridges (Bird 1978), although they have also been called 'mini-cheniers' (Davis *et al.* 1977) on the grounds that they formed on a marshy foundation. The pattern of these ridges varies along the shores of Lake Reeve, some sectors having advanced more rapidly to form forelands which may eventually coalesce, segmenting this lagoon. However, intermittent wave action in Lake Reeve, compared with perennial lagoons such as Cunninghame Arm, renders this a very slow process.

DISCUSSION

Although the surveys carried out in 1957-59 were intended only to detect shoreline changes in progress at that time, they have provided a basis for determining the pattern of change around the Gippsland Lakes in the ensuing quarter-century (Fig. 1). The changes have been less than the author would have predicted in 1959. This is partly because some sectors of the lake shoreline have been stabilised artificially, but two other factors are relevant. First, much of the shoreline change has taken place during occasional stormy periods or episodes of flooding. In 1957-59 the lakes' shoreline showed many features that had developed during the severe floods in 1952, notably erosion scars that then suggested a relatively rapid rate of shoreline recession. Although there have been subsequent floods, notably in 1971 and 1978, and a number of stormy periods, the past 25 years may not have been as boisterous as the preceding 25 years, which included major episodes of river flooding in 1934, 1949, 1951, 1952, and 1953. Second, there has been a marked change since 1957-59 in the extent of water weeds, notably *Zostera* spp., in the shallow nearshore waters of Lake Victoria and Lake King. In the nineteen-fifties there was very little *Zostera* growth in these lakes, possibly because of the presence of vast numbers of crabs (*Paragrapsus* spp.), but since the early nineteen-sixties the crab population has diminished and *Zostera* growth has become extensive and luxuriant. Wave action is much reduced in sectors where *Zostera* is present, and the increase in this weed growth has un-

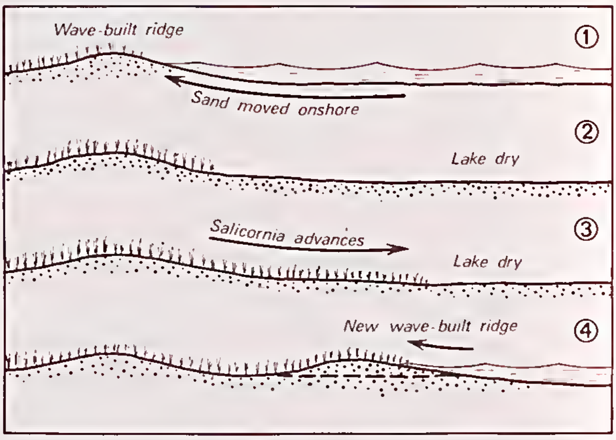

Fig. 10—Evolution of wave-built sandy beach ridges on the shores of Lake Reeve is related to episodes of high lake level, alternating with phases when the lake dries out, and vegetation (mainly *Salicornia*) spreads forward to set the scene for the next beach ridge formation.

doubtedly slowed down erosion on the lake shoreline in the past two decades.

Geomorphological studies in 1957-59 (Bird 1978) emphasised the role of shore-line reedswamp in promoting silt accretion in the Gippsland Lakes, and identified the loss of much of the former reedswamp fringe as the main reason for widespread shoreline erosion, especially on swampy sectors. During the past 25 years, there has been further reedswamp reduction, and consequent onset of shoreline erosion, particularly in Lake Wellington. However, many of the changes that have occurred on the shoreline of the Gippsland Lakes in the past 25 years are the result of sand movement alongshore and across lake floors, particularly from west to east, and its accumulation on spits and forelands, west-facing shores and embayments.

In contemplating the changes that may occur in the next 25 years, the significance of sand moving down the rivers, especially the Latrobe, the Avon, and the Tambo, must also be considered. If there is frequent and severe river flooding during this period, these rivers will be delivering sand to the lakes, and shoreline sectors now swampy and eroding will become fringed by sandy beaches. It seems likely that within the next century the eroding silty deltas of these rivers will give place to growing sandy deltas. Meanwhile, the modern enthusiasm for dumping sand dredged from navigation channels and from rivers on sectors of the lake shore could accelerate this increase in sandiness on the shorelines of the Gippsland Lakes.

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